EOID Evaluation and Automated Target Recognition

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LONG-TERM GOAL

The Navy is in the early stages of incorporating high resolution Electro-Optic IDentification (EOID) sensors into shallow water littoral zone minehunting systems on towed, remotely operated, and autonomous platforms. These downlooking laser-based sensors operate at unparalleled standoff ranges in visible wavelengths to image and identify mine-like objects that have been detected through other sensing means such as magnetic induction and various modes of acoustic imaging.

Our long term goal is to provide a robust automated target cueing and identification capability for use with these imaging sensors. It is also our goal to assist the Navy in understanding, quantifying, and ultimately predicting the detection, identification, and false alarm performance of these systems in varied conditions of water quality, ambient light, and range to target.

OBJECTIVES

Our primary CY2001 objective was to advance the hybrid multi-strategy Object ID architecture first introduced in 1999 and expanded upon in 2000 to the point where end-to-end coarse object classification can be performed and assessed. This functionality allows target cueing to aid a man-in-the-loop decision, permits positive ID of some uniquely shaped mine types, and finds Objects of Interest whose internal detail must be scrutinized before a mine/no-mine declaration can be made.

Our second objective was to integrate the algorithm suite into a PC/GUI-based demonstration and evaluation tool. This tool hosts algorithm development and performance assessment, and supports the review, ground truthing, data reduction, and analysis of the large quantities of imagery collected in the August 2001 EOID evaluation tests off Panama City, FL. This data set spans a broad range of ambient light, water quality, target type, and range to target conditions and will be invaluable to algorithm performance and limitation assessments across the operational domain.

APPROACH

Mine cueing and identification are mechanized through an algorithm architecture that combines proven Raytheon target cueing and object classification / identification approaches from other military applications with new Computer Vision techniques. This hybrid architecture is presented in figure 1.

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14. ABSTRACT
The Navy is in the early stages of incorporating high resolution Electro-Optic IDentification (EOID) sensors into shallow water littoral zone minehunting systems on towed, remotely operated, and autonomous platforms. These downlooking laser-based sensors operate at unparalleled standoff ranges in visible wavelengths to image and identify mine-like objects that have been detected through other sensing means such as magnetic induction and various modes of acoustic imaging.

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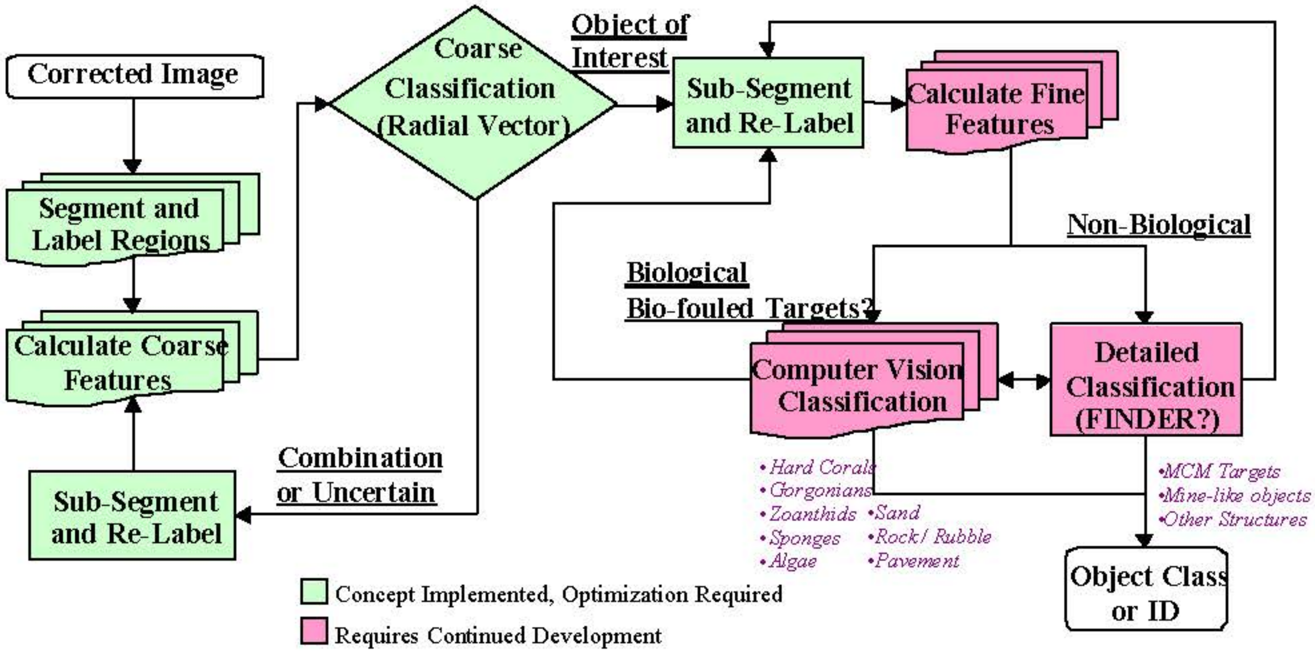


Figure 1. Multi-Strategy Object Identification Processing Flow Architecture

Within this architecture, K-Means Clustering is used to segment the image into local pixel groups, or "regions", based on amplitude similarity. Size, shape, and other features are derived from the region's boundary pixels. These features are evaluated using a coarse classifier to determine if the region is a mine-like object or possibly a mine in easier cases where high signal-to-noise-plus-clutter ratios exist.

Regions with entire boundaries that are erratically shaped in both local and global detail are part of the noise and clutter background and are quickly discarded. Target-sized regions with smooth boundaries and boundaries with high frequency spatial noise that can be removed through local morphological processing may be man-made and are classified as Objects of Interest if their coarse shapes are similar to that of a modeled target. In cases where the object shape is uniquely that of a modeled target, a definitive ID may be made at this juncture. If these smooth boundary regions are smaller than a target, they are fed back into the sub-segmenting and re-labeling process where they are merged, if appropriate, with adjacent regions. These merged regions return to the coarse classifier and become Objects of Interest if they are now target-like. Finally, larger regions whose boundaries are partly smooth and partly erratic may contain a man-made target and some background. These regions are fed back to localized sub-segmentation and re-labeling processing in an attempt to split the object pixels from those of the background. Features are calculated for the extracted sub-regions and coarse classification is again performed to determine Objects of Interest.

Objects of Interest, their visual representations, and their locations in the larger image are passed directly to a man-in-the-loop for manual decision making in a process termed "cueing", and/or are routed to detailed classification processing. Here, the object is subject to internal segmentation and fine feature extraction. Fine features are descriptors of sub-structures on the object that have 3-D relief and/or optical reflectance properties that differ from neighboring surfaces. The accumulation of fine features, including their relative positions, constitutes a "strength-of-evidence" buildup that is exploited for ID purposes in either the Computer Vision or the Detailed Classification algorithms.

WORK COMPLETED

During the Key West Survey (Underwater Object Identification in Laser Line Scan Imagery) contract (Reference OP16 year-end reports for CY1999 and CY2000), the Multi-Strategy Object Identification Processing Flow Architecture shown in Figure 1was defined and the segmentation and region labeling components were implemented.

This year, a coarse classifier and accompanying feature extraction were implemented and tested, and a PC/GUI-based end-to-end version of all implemented routines was created. This GUI tool exists in a C++ software development environment and, in addition to supporting algorithm development and test, provides an integrated capability to review, ground-truth, process, and analyze the uniquely formatted raw imagery and ancillary data recorded during sensor operations. This tool was used in the August 2001 EOID Evaluation trials at Panama City, FL. to ground truth all visible mine target images collected and to categorize these images by quality to aid algorithm test database selection.

The algorithm selected for Coarse Classification, the "Radial Vector Classifier" (RVC), is depicted in Figure 2 and was originally developed by Raytheon to identify ships and aircraft in high resolution single channel passive infrared camera imagery. This approach employs a correlation metric to compare segmented region silhouettes to a stored reference library of potential targets. The silhouette descriptor is termed the radial vector (RV) feature and is derived from contiguous region boundary pixels.

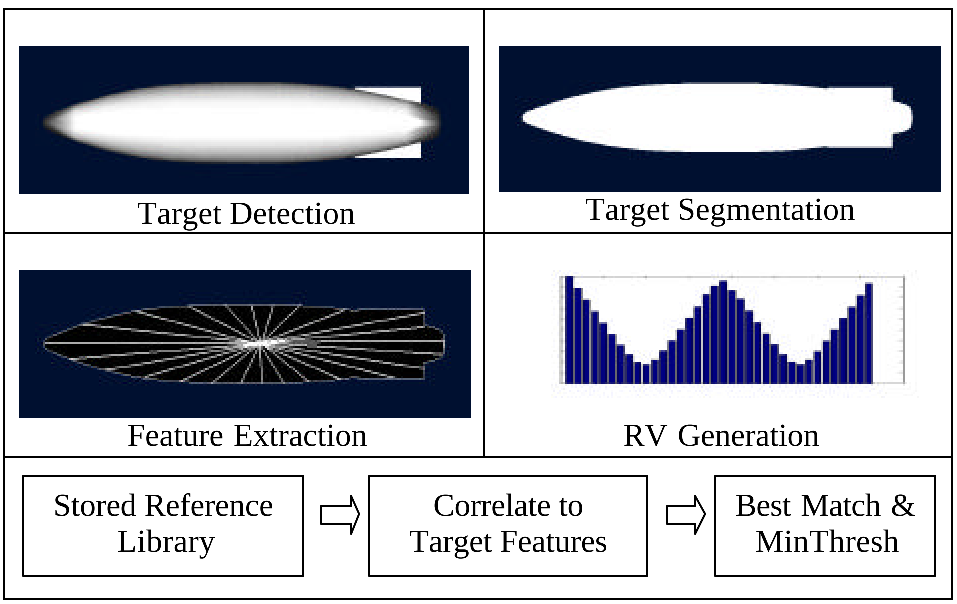
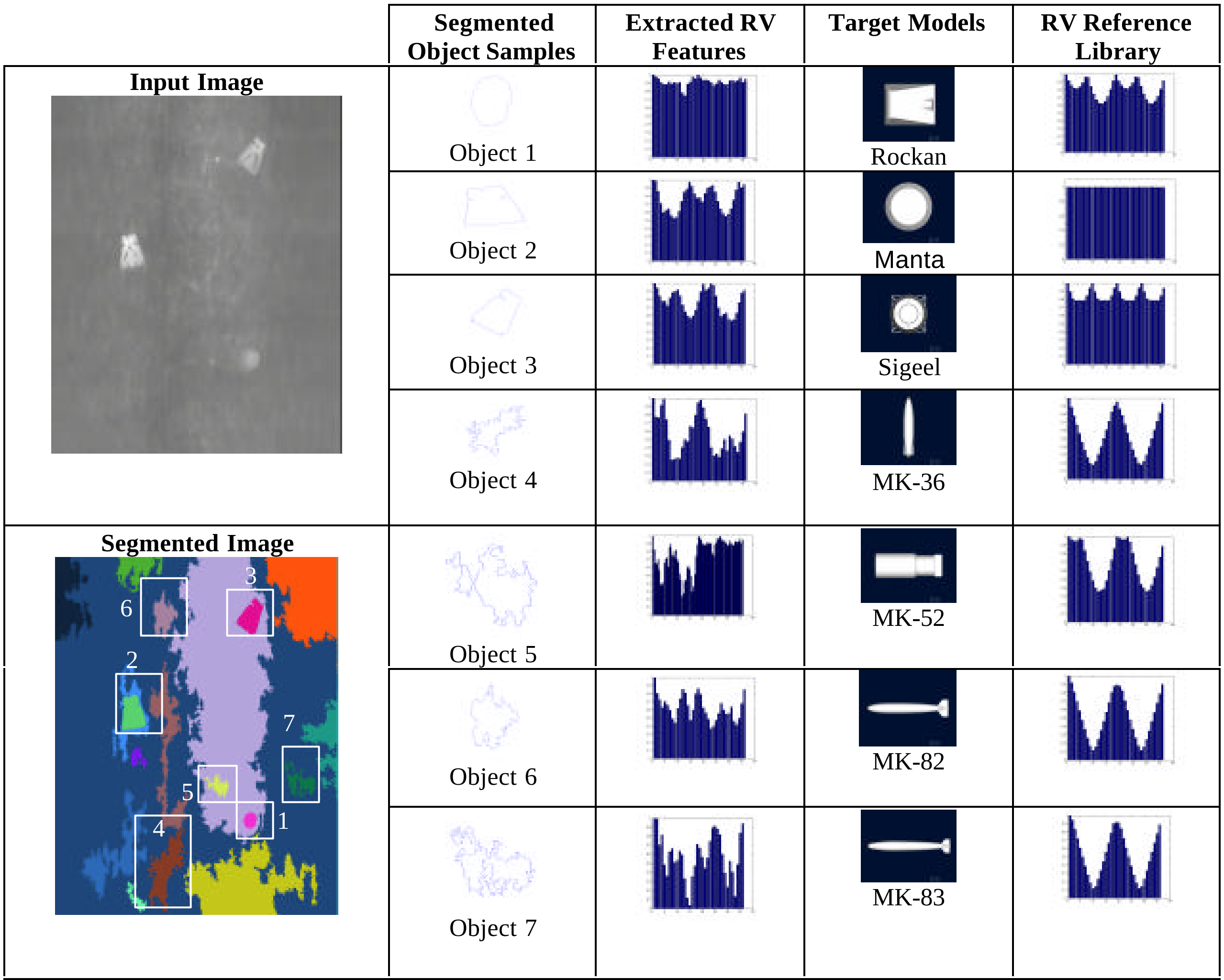


Figure 2: Radial Vector (RV) Classification Algorithm

An RV feature consists of N values representing the vector lengths from the region geometric centroid to the boundary pixels at equally spaced angles. The N values are clockwise ordered and length normalized to the longest vector to achieve rotation and size invariance and thus reduce the number of comparisons made with the target reference library. The RV feature is then correlated with each entry in the target library and a set of confidence values is obtained. An empirical minimum threshold on the best match confidence factor can then be applied to declare Cues or Objects of Interest.

RESULTS

In Figure 3 below, the RV Classifier operates on Laser Line Scan imagery collected off the Panama City, FL. coast. All three targets in the scene are correctly identified with significantly higher confidence factors than the clutter regions.



Object #	Target Correlation Confidences							Results		
	Rockan	Manta	Sigeel	MK-36	MK-52	MK-82	MK-83	Best Match	High Confidence?	Ground Truth
1	50%	**77%**	73%	1%	5%	1%	1%	Manta	Yes	Manta
2	**72%**	5%	39%	3%	16%	2%	3%	Rockan	Yes	Rockan
3	**69%**	5%	33%	4%	5%	3%	4%	Rockan	Yes	Rockan
4	3%	1%	2%	**43%**	16%	33%	33%	MK-36	No	Clutter
5	7%	1%	4%	12%	**23%**	10%	9%	MK-52	No	Clutter
6	9%	1%	5%	9%	**12%**	7%	7%	MK-52	No	Clutter
7	4%	1%	2%	6%	**9%**	6%	6%	MK-52	No	Clutter

Figure 3: The RV Classifier Correctly Identifies Mine Targets in Laser Line Scan Imagery

A target and clutter image database is being established for algorithm development and performance / robustness assessments. It will consists of field deployment imagery and synthetic scenes from validated sensor and environmental models. The bulk of the field data will come from the Panama City August 2001 testing. This data has been reviewed and categorized by image quality as shown in

Figure 4. The nine pictures span the quality domain from a signal-to-noise (S/N) versus signal-to-clutter (S/C) perspective, in which detection and identification probabilities improve from lower left to upper right, albeit not in a linear fashion. The upper and lower numbers to the right of each box are the quantity of mine and clutter object (tire, crab trap, ladder, culvert, etc.) data samples repectively. This database will be cross-referenced to environmental and run geometry information and will allow our goal of assessing performance versus operational variables to be addressed in the CY2002.

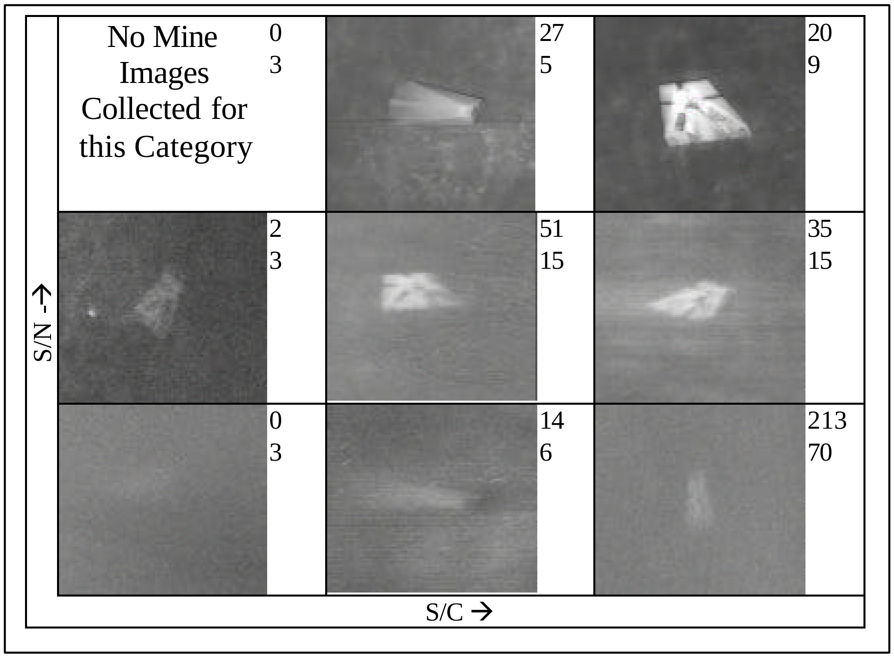


Figure 4: Target and Clutter Database Spans the Image Quality Domain

IMPACT/APPLICATION

A robust target cueing and identification capability developed under this project will have insertion potential into Navy minehunting and neutralization systems such as AQS-20/X, RMS, AMNS, etc. Further development of the biological species ID capability provided by the Computer Vision Classifier has utility in environmental health surveys and species population and habitat studies.

TRANSITIONS

Although this work is not yet sufficiently mature for transition to other users, it is itself a transition from other DoD efforts. Specifically, mine cueing techniques considered for this project were developed under the US Army CECOM's Airborne Standoff Minefield Detection (ASTAMIDS) program; the candidate algorithm for Detailed Classification was developed for insertion into the US Army AMCOM's BAT (Brilliant Antitank Submunition) program.

RELATED PROJECTS

OP73 – "Electro-Optic Identification Research: Performance Prediction Model". Dr. Starnd's model can create synthetic images across a broad domain of operational conditions for algorithm testing.

OP58 – "Environmental Characterization of Mine Countermeasure Test Ranges: Hydrography and Water Column Optics" , Phinney and Yentsch.

REFERENCES

The algorithms discussed herein have been developed under Raytheon proprietary funding and as such do not have publicly available references. An exception to this is the “K-Means Clustering” algorithm which is a textbook segmentation approach in the digital image processing community.

There are multiple references discussing the foundation upon which the computer vision concepts detailed herein are developed. A list of references is available upon request.